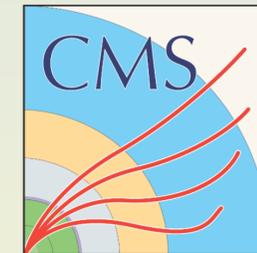




# The Fast Beam Condition Monitor as a standalone luminometer of the CMS experiment at the HL-LHC

Mohammad Sedghi on behalf of CMS Collaboration

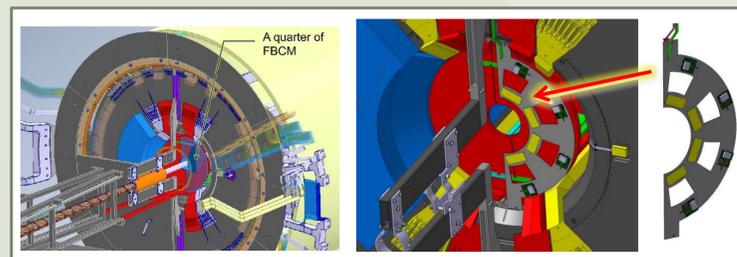
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## Abstract

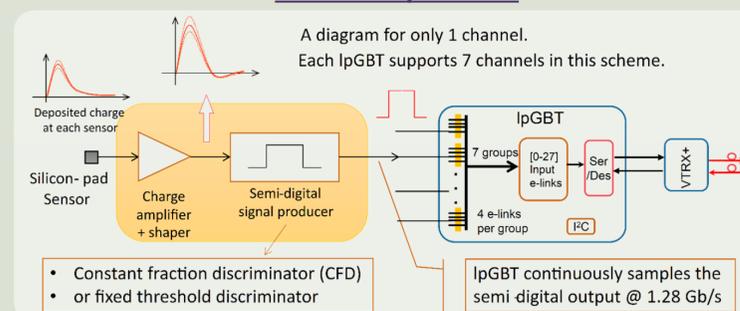
In the Phase-2 CMS upgrade, a luminosity uncertainty of 1% is targeted. To achieve this goal, measurements from multiple luminometers with orthogonal systematics are required. A standalone luminometer, the Fast Beam Condition Monitor (FBCM) is being designed for online bunch-by-bunch luminosity measurement. Its fast timing properties also enable the measurement of beam induced background. In this poster, the hardware architecture and the read-out protocol of the FBCM is presented. The expected performance with a simple behavioral model of the front-end comprising a constant fraction discriminator is discussed, though the final implementation in the ASIC is still under discussion.

## Fast Beam Conditions Monitor (FBCM)



It is proposed in this document to install the FBCM behind disk 4 of the TEPX system, close to the bulkhead, corresponding to  $8 < r < 30$  cm and  $277 < |z| < 290$  cm, as illustrated in above. The FBCM will be divided into four quarters, where one quarter covers one half at one end of the detector.

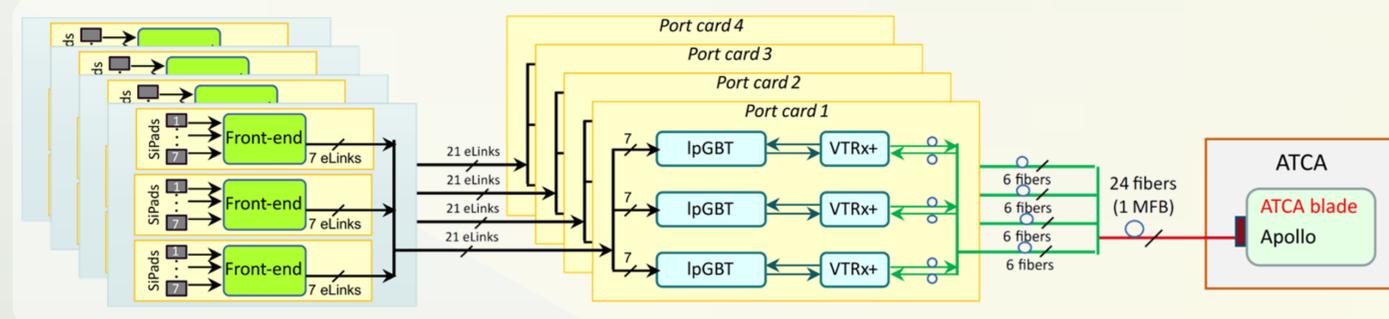
## Read-out protocol



Once a hit is received on a silicon-pad sensor, the generated ionization charge produces a short pulse. The signal will be amplified and shaped in the front-end ASIC, then a non-clocked digital output pulse will be produced. The IpGBT, a chip for low power gigabit transmission, continuously samples the output signal of the front-end channels. Then the data will be sent to the backend by versatile link transceivers (VTRx+).

## FBCM readout architecture

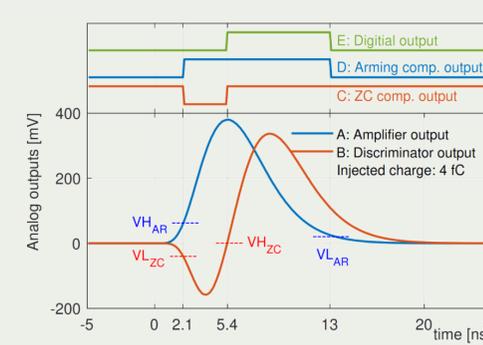
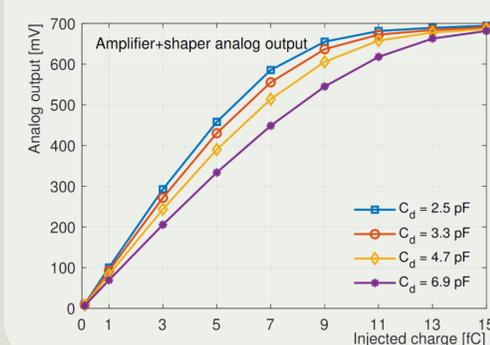
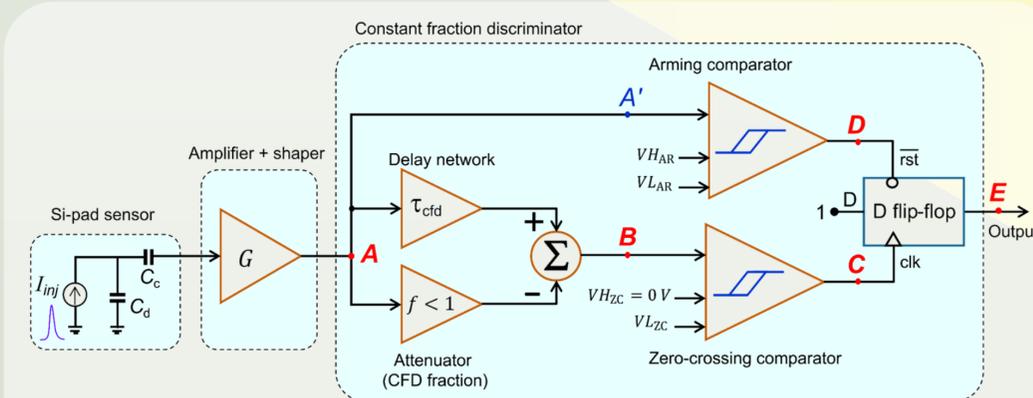
Each front-end module includes 21 silicon-pad sensors and the relevant electronics. Each hybrid port card includes three IpGBT and three VTRx+ to send and receive data via optical fibers. At the back-end, blades based on Advanced Telecommunications Computing Architecture (ATCA) will be employed to histogram the number of hits per BX.



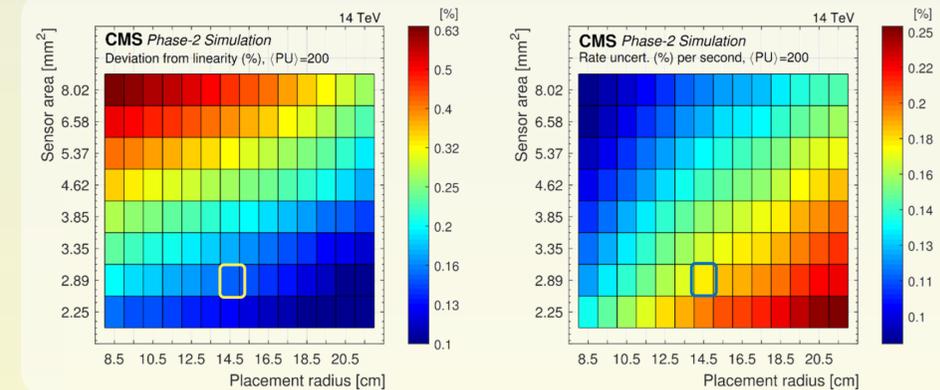
## Front-end with constant fraction discriminator as a case-study

The front-end ASIC could be designed with either a CFD or a fixed-threshold discriminator with time-walk compensation, the front-end ASIC is modeled as a CFD for this study. The choice between these two architectures will be made during the engineering design stage, taking into account performance and existing ASIC building blocks in 65 nm technology that can be adapted for use in the FBCM ASIC. The transimpedance amplifier is similar to that of the BCM1F, and the CFD block has been inspired by the VFAT3 architecture.

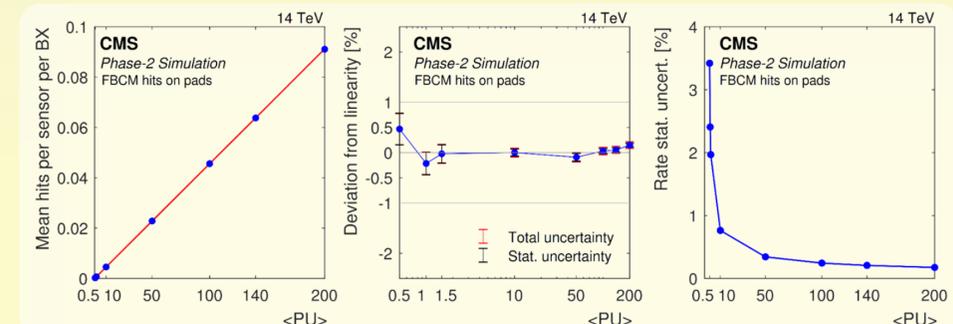
Block diagram of the front-end model developed for the FBCM digitizer, employing an amplifier followed by a CFD.  $C_c$  and  $C_d$ : coupling and sensor capacitance,  $G$ : amplifier gain,  $\tau_{cf}$  and  $f$ : CFD shaping network delay and the fraction parameter,  $V_{Lx}$  and  $V_{Hx}$ : lower and upper thresholds of hysteresis comparators. The signals at nodes A (A') and B are in differential pairs. The bottom-left panel depicts the output voltage at node A as function of accumulated injected charge. The bottom-right panel shows the variation of signals at nodes A-E with respect to time, assuming a sensor size of 2.89 mm<sup>2</sup> with collected charge of 4 fC.



## FBCM expected performance



Deviation from linearity (left), statistical uncertainty in the rate (right), all evaluated at average pileup 200, for different sensor sizes and placement radii, assuming 336 sensors in FBCM.



The mean number of hits per BX (left), the deviation from linearity (center), and the statistical uncertainty in the rate (right) estimated at pileup 200 with an integration period of 1 second for 336 sensors, each with a area of 2.89 mm<sup>2</sup>, at  $r \approx 14.5$  cm.

## Summary

Simulation results, assuming a CFD architecture, show that the FBCM will provide the acceptable statistical uncertainty and deviation from linearity by employing 336 silicon-pad sensors. In addition, the front-end with sensitivity to at least 6000 electrons will satisfy the longevity constraints for an exposure of 1 MeV neutron equivalent fluence of  $3.5 \times 10^{15}$  per cm<sup>2</sup>. Even though this study was with the assumption of using a CFD in the front-end, FBCM ASIC design will probably make the most use of existing 65 nm blocks, such as a fixed threshold discriminator with time-walk compensation.

## References

- [1] The CMS Collaboration, *The Phase-2 Upgrade of the CMS Beam Radiation, Instrumentation, and Luminosity Detectors: Conceptual Design*. CERN-CMS-NOTE-2019-008.
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- [4] D. Abbaneo et al., "Design of a constant fraction discriminator for the VFAT3 front-end ASIC of the CMS GEM detector", *Journal of Instrumentation* **11** (2016)